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AIDING BLISTER RUST CONTROL BY SILVICULTURAL MEASURES IN THE WESTERN WHITE PINE TYPE[1]

By Virgil D. Moss, *forest ecologist, Region IV, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration,* and Charles A. Wellner, *forester, Northern Rocky Mountain Forest and Range Experiment Station, Forest Service*[2]

CONTENTS

	Page
Introduction	1
Ribes ecology	3
Importance and distribution of species	3
Growth of ribes in forest stands	5
Seed production and storage	5
Seed germination	8
Seedling survival	10
Blister rust infection on ribes	12
Blister rust infection on pine	12
Blister rust in relation to timber management	14
Cuttings in mature and overmature stands	16
Prescribed broadcast burning	23
Cuttings in immature stands	25
Unit management	29
Summary	30
Literature cited	32

INTRODUCTION

The forest industry of the Inland Empire depends on the production of western white pine (*Pinus monticola* Dougl.) as a major species. Continued production of this tree is impossible unless white pine blister rust (*Cronartium ribicola* Fischer) is controlled. Existing merchantable timber can and probably will be harvested before serious losses occur, but the young growth that will determine the future of the industry is the great value at stake. The stakes are large. According to Matthews and Hutchison (*7*),[3] "A lumber industry with white pine has greater prospects for security, stability, and prosperity

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[3] Italic numbers in parentheses refer to Literature Cited, p. 32.

245915—53——1

than an industry dependent solely upon the other less valuable kinds of timber. To the extent that the lumber industry is more secure and prosperous, the communities of the white pine belt will be more secure and prosperous."

Blister rust can be controlled through suppression of ribes,[4] the alternate hosts of the disease. Control is a tremendous undertaking; it is probably the most important and urgent work relating to the growth of timber in the western white pine type. Western white pine forests of the Inland Empire (fig. 1) embrace an area of 3,600,000

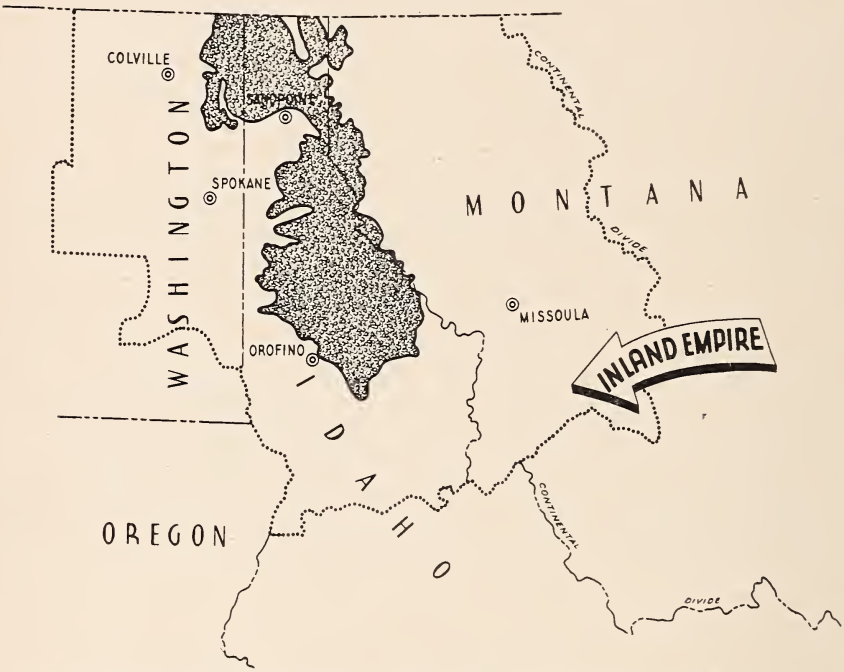

FIGURE 1.—Area in Inland Empire where western white pine is of great commercial importance and where blister rust control is centered.

acres (Matthews and Hutchison 7). This acreage indicates the maximum possible size of the program. The designated task, however, is considerably smaller and more specific. The principle of the white pine working unit provides for selection of geographic units of about 500 to 5,000 acres, in which the maximum quantities of white pine can be produced at the least cost for blister rust control. These working units are tracts within which blister rust infection on pine occurs readily but the pine is subject to slight danger of infection from outside. Recent analyses show that blister rust must be suppressed on 1,700,000 acres to maintain an annual cut for the next 80 years somewhere near the present level of 200 to 300 million board feet, and an eventual annual cut after 80 years of 500 million board feet. The present rate of progress will provide protection from blister rust on only 900,000 acres.

[4] The generic name "*Ribes*" and the common name "ribes" are used in this circular to indicate both currants and gooseberries.

Effective and economical control of blister rust necessitates a thorough working knowledge of the occurrence and life history of ribes in forest stands, the incidence and spread of the disease on ribes and white pine, and, finally, the influence of timber-management methods on ribes establishment and growth. The purpose of this circular is to provide such information as a guide to forest practices that will aid in the control of blister rust.

RIBES ECOLOGY

Importance and Distribution of Species

Four species of *Ribes* occurring in large numbers and widely distributed in the western white pine type are of major importance in the blister rust control program. They are *viscosissimum* Pursh. (sticky currant), *lacustre* (Pers.) Poir. (prickly currant), *inerme* (Rydb.) Cov. and Britt. (white-stemmed gooseberry), and *petiolare* Dougl. (western black currant). *Ribes viscosissimum* and *lacustre* cause the most serious problem because of their large numbers and close association with white pine on the upland timber-producing slopes. From the inception of blister rust control work in 1923 through 1950, these two species have represented 93 percent of the 454,803,000 ribes plants eradicated.

Ribes viscosissimum

From 1923 through 1950 approximately 229,220,000 *viscosissimum* plants were destroyed; this is 50 percent of the total number of ribes plants eradicated. This species is called the sticky currant because of its viscid or resinous leaves, fruits, and young stems. The bush is of erect growth, 3 to 5 feet high, and spineless. Leaves are kidney-shaped, 5 to 8 cm. wide, hairy and glandular-hairy on both surfaces; lobes, usually 5, are short and rounded. Petioles are densely glandular-hairy and much dilated at the base. Greenish-white or pinkish flowers are borne on 3 to 13 flowered ascending racemes. The berry is black or purplish-black, hairy and glandular bristly, noticeably ribbed, and almost dry. A strong, rather spicy and pungent odor is one of the chief characteristics used in distinguishing *viscosissimum* from other upland ribes and associated vegetation.

Common habitats for *viscosissimum* are open ridge tops, burns, cut-over lands, and right-of-way clearings. It attains optimum development on moderately cool, moist, north and east exposures. A deep taproot enables it to grow more extensively on hot, dry, south and west slopes than any of the other *Ribes* species in the western white pine type. Because of heavy seed production and prolonged survival of seed stored in the humus, it regenerates in greater numbers than do other species after any major forest disturbance. It is intolerant of more than 40-percent shade; thus its natural suppression is materially aided by partial shade. Under forest cover it occurs most abundantly in white pine stands having western larch (*Larix occidentalis* Nutt.), lodgepole pine (*Pinus contorta* Loud.), Douglas fir (*Pseudotsuga taxifolia* (Lamb) Britt.), Engelmann spruce (*Picea engelmanni* (Parry) Engelm.) and alpine fir (*Abies lasiocarpa* (Hook.) Nutt.)

as associates. Populations of *viscosissimum* decrease as the forest gets older and as the proportion of the shade-tolerant tree species—grand fir (*Abies grandis* Lindl.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western redcedar (*Thuja plicata* D. Don.)—increase. By the time these dense-shading forests reach 60 years of age, *viscosissimum* is restricted to open ridge tops and rock outcroppings.

Ribes lacustre

Ribes lacustre is second in abundance and distribution. The 194,967,000 *lacustre* bushes eradicated during the period 1923–50 represent 43 percent of the total. It is called the prickly currant because of its spiny stems. In the open it is an erect shrub 3 to 4 feet high; in the shade it is reclining and often trailing. The branch internodes are densely spiny except in shade, where spines are weak, like coarse hairs. The nodes are armed with 3 to 9 stout spines united into a semicircle at the base. The leaves are nearly circular in outline, 3 to 5 cm. wide, thin, glabrous or nearly so on both surfaces, and deeply 5 to 7 lobed. The petioles are slender, glandular-hairy, and bristly. The racemes bear 10 to 15 flowers, which are green, tinged with purple, saucer-shaped, and drooping. The berry is purplish-black and covered with weak, gland-tipped, coarse hairs. The bush has no distinctive odor.

Ribes lacustre is the most cosmopolitan in growth habit of all ribes in the western white pine type. Optimum development occurs in partial shade along streams. It is found sparingly on south and west slopes and in large numbers on north and east exposures.

In the western white pine stands *Ribes lacustre* is more tolerant of shade than other *Ribes* species, often persisting under a closed canopy long after most shrubs have disappeared. The natural suppression of seedlings is slow under less than 75 percent of full shade. Differing from *viscosissimum* in its requirement of soil moisture *lacustre* occurs less frequently with western larch, lodgepole pine, and Douglas fir associates, and more abundantly with western redcedar, western hemlock, and grand fir. At higher elevations both *Ribes* species occur in about equal abundance with the associates Engelmann spruce and alpine fir.

Ribes inerme and Ribes petiolare

The stream-type species are *Ribes inerme* and *petiolare*. Stream-type vegetation of which these species are a part occurs on the flat or bench areas of abundant soil moisture along streams. Here the vegetation consists chiefly of luxuriant brush and herbaceous growth. Though limited in distribution and numbers, these two species are important because of their high susceptibility to blister rust and because of their occurrence within a zone of high humidity favoring rust development. *Ribes petiolare* was responsible for many of the initial long-range rust introductions into the Inland Empire. The stream-type species require direct control measures (chemical, mechanical, and hand) for their eradication. Because of abundant soil moisture for ribes development, such areas are recognized as permanent ribes sites and require periodic inspection for possible ribes recurrence.

Other Native Ribes

Four other species of *Ribes* are of minor importance in blister rust control work—*irriguum* (Dougl.) Cov. and Britt. (Idaho gooseberry), *triste* Pall. (American red currant), *coloradense* Coville (Colorado currant), and *acerifolium* Howell (mapleleaf currant). Their distribution and numbers, though not of regional importance, have been significant in some drainages.

Growth of Ribes in Forest Stands

Ribes bushes persist in forest stands until their demands for light, moisture, and nutrients exceed the supplies. Ordinarily, they are suppressed after about 20 years in fully stocked timber stands, although they may survive longer, depending upon the composition and density of the timber. They die out first in white pine stands where the proportion of shade-tolerant western hemlock, grand fir, or western redcedar is high. These trees, as an understory in white pine stands, are highly effective in suppressing ribes.

Shade limits the growth and regeneration of ribes by restraining fruiting and normal foliage functions. The first species of *Ribes* to be eliminated by forest competition is *viscosissimum*, followed in later years by *lacustre*. The latter species persists longer because of its ability to reproduce vegetatively from layering stems and because of its greater tolerance to forest shade. In timber stands 20 to 40 years old ribes plants are confined largely to openings. In well-stocked stands over 40 years old, they are found on ridge tops, rock outcroppings, and stream benches.

In stream-type vegetation, ribes bushes often constitute an important part of the shrub cover and, in general, maintain themselves in competition with other plants. Occasionally the bushes will be crowded out by the development of dense thickets of taller shrubs, and by the forest canopy closing over narrow stream benches. Stream-type ribes plants occur in a narrow belt more or less distinct from the timber-producing upland slopes and therefore are somewhat immune to the effects of fire and logging. Nevertheless, if a fairly complete forest cover is left along streams, it can be a material aid to blister rust control.

Seed Production and Storage

In the years preceding their natural suppression from forest stands, the upland species of *Ribes* produce great quantities of seeds, which are deposited on the ground near each bush. Seed is produced during the years mature bushes are growing vigorously. Both upland species, under favorable conditions, will start to fruit in their third year of growth. Not until the fifth year, however, does seed production become general and soil storage of viable seed become a major problem. *Ribes viscosissimum* produces from 15 to 25 berries, each having about 50 seeds, and *lacustre* produces from 50 to 75 berries, each having about 8 seeds.

Ribes bushes produce seed prolifically on optimum sites. Seed crops usually are large every 2 or 3 years. The amount of seed produced is controlled by such factors as weather at the time of flowering, the activity of insect pollinators, and the injurious effects of late-

spring frosts or summer drought on the development of fruit. Fruit production becomes progressively poorer as the numbers of ribes bushes are reduced by eradication work and by natural suppression, because flower fertilization requires cross-pollination (Offord and coworkers *10*). Eventually, scarcity of neighboring bushes to supply pollen may become a major factor in reducing seed production, thus favoring the suppression of ribes within control areas.

Seeding continues until forest competition reduces bush vigor or until the plants begin to degenerate. The seeds, being wingless and comparatively heavy, fall to the ground near the parent bush unless they are moved away by water. Birds, rodents, or other animals are not important in the dissemination of ribes seed.

Seeds that fail to germinate soon after dissemination eventually reach the bottom of the organic soil mantle through a gradual sifting process caused by the combined action of water, wind, and animals, and by the slow disintegration of the organic mantle from below by soil organisms. The rate of this disintegration is fairly constant throughout the life of a timber stand. In the first 20 years, when ribes bushes are producing most of their seed, the organic mantle is thin; consequently, much seed is deposited on top of the soil. Seeds produced after litter begins to accumulate eventually come to rest beneath the organic layer on top of the mineral soil (table 1).

TABLE 1.—*Percentage of ribes seeds in different layers of the organic soil mantle under timber stands of various ages*

Organic layer	21–60 years	61–100 years	101–200 years	200+ years
Litter (undecomposed)	3	0	0	0
F (partly decomposed)	24	21	16	0
H (well decomposed)	73	79	84	100

Some ribes seeds remain viable throughout the life of a forest stand. The number depends upon how favorable forest conditions have been for storage of seeds within the organic soil mantle. Low soil temperature contributes greatly to their longevity. The thick floor mantle that provides insulation for seeds also inhibits the exchange of gases involved in the germination process. Longevity is further facilitated by the hard shell on ribes seeds restricting the absorption of moisture and oxygen, essential for the germination process, until the coat is made permeable by the slow deteriorating action of weathering and soil organisms.

The number of viable ribes seeds in the forest floor gradually decreases as the age of a forest stand increases. This decrease results mainly from the exhaustion of foods by the respiration of seeds over a long period of storage.

The percentages of viable seeds in timber stands of various ages compared with stands 1 to 20 years old, are shown below:

Years	*Percent*
21 to 60	63
61 to 100	27
101 to 200	16
200+	4

In laboratory tests about 67 percent of new seed was found to germinate.

The life span of ribes seeds in the forest floor is affected by the composition and density of a timber stand, the exposure, the amount of sunlight reaching the forest floor, and the character of the soil. The composition will shorten or lengthen the life of ribes seeds depending upon tree species. The dense canopy formed by western hemlock, western redcedar, and grand fir favors their longevity. A large amount of sunlight filtering through the canopy of western larch, lodgepole pine, ponderosa pine, and Douglas fir associates shortens the life of ribes seeds.

North and east exposures, because of lower temperature and greater moisture, are more suitable for seed storage than south and west exposures. Similarly, the cool, moist sites of high elevations are more suitable than warmer and dryer areas at low elevations. Shallow soils underlaid with sand and gravel and sandy-loam soils, because they are generally hot and dry, and soils that stay soggy, usually shorten the life of ribes seeds.

Estimating Potential Ribes Populations

The number of viable ribes seeds stored in the forest floor can be estimated by studying the ecologic history of the area. The number varies according to the amount of seed produced and the time and conditions of storage. The ability to estimate the ribes population that is likely to occur after major disturbances, such as logging and the use of fire for slash disposal, can be a useful tool in the hands of the forest manager. It can help him to select timber-harvesting practices which will facilitate subsequent blister rust control. Hence, determination of the potential ribes seedling population in advance of logging is important in correlating cutting practices with blister rust control. A guide to aid in estimating potential ribes populations is given below.

Populations averaging less than 25 bushes per acre:

1. Stands on south and west slopes that originated after two or more fires occurring less than 20 years apart.
2. Stands that originated after two or more fires which together completely consumed the organic mantle down to the mineral soil.
3. Stands overmature, more than 200 years old, fully stocked since inception, and composed largely of western hemlock and western redcedar.
4. Stands with a high proportion of western larch, lodgepole pine, ponderosa pine, and Douglas fir growing in shallow soil with a substratum of sand, gravel, or rock.

Populations averaging more than 25 bushes per acre:

1. Stands that originated after a single burn.
2. Stands on north and east exposures that originated after two or more natural fires occurring more than 10 years apart.
3. Stands that originated after one or more fires, none of which completely consumed the organic mantle down to the mineral soil.
4. Open-grown stands on north and east exposures with inadequate cover to suppress ribes bushes or prevent their continued seeding.
5. Crests of prominent ridges from which ribes bushes are rarely suppressed by forest cover.
6. Heads of drainages where streams finger out over upland slopes and create habitats more favorable for shrubs than for trees.

Seed Germination

Any forest activity, such as logging and fire, that disturbs or consumes the organic soil mantle will stimulate the germination of stored ribes seeds. The number of stored seeds germinating from logging operations (road construction and skidding logs) will depend upon the extent that the organic mantle is mechanically disturbed and the mineral soil exposed.

The forest floor is mechanically disturbed in increasing amounts in skidding logs with power jammers, horses, and caterpillars. Most of the soil disturbance caused by jammer logging comes from the construction of truck roads and not from skidding logs, because of the small amount of mineral soil exposed in trailing a few logs over the same piece of ground. Deep-rutted trails exposing large amounts of mineral soil result from skidding large numbers of logs over the same trail with horses and caterpillars. Much less mineral soil is exposed from horse than caterpillar logging.

The soil disturbance in skidding operations is also affected by the length of the log, the season of logging, and the steepness of slope. When long logs (32 feet) are skidded, they disturb the floor less than short logs (16 feet), and still less than full-length trees. Winter logging over frozen ground and snow, except for the construction of truck roads, will not cause many ribes seeds to germinate. Germination caused by winter logging is less than 5 percent of that caused by summer logging. The amount of mineral soil exposed by logging increases with the steepness of the slope.

Fire employed for the disposal of piles of logging slash and for the reduction of hazardous fuels in prescribed broadcast burning affects the germination of stored ribes seeds by the temperature it produces on top of the mineral soil surface. The number of stored seeds germinating on burned-over surfaces will decrease as fire consumes the organic mantle.

Heavy burning, in consuming the entire organic mantle, will destroy most of the stored ribes seeds. A medium burn, which consumes the organic mantle down to the well-decomposed humus layer, destroys about one-tenth of the number of stored seeds killed by heavy burning and produces a highly favorable condition for the remainder to germinate. By removing only the litter, a light burn establishes the best conditions for germination without appreciably destroying seeds stored in the lower part of the organic mantle. In a stand 60 to 80 years old in the Kaniksu National Forest a medium burn resulted in 32 percent fewer seedlings and a heavy burn in 94 percent fewer than the number from a light burn.

The desirable time to burn to destroy ribes seed is the fall before enough rain has fallen to prevent fire from consuming the organic mantle down to mineral soil.

If the organic mantle is not disturbed mechanically and is not consumed by fire, soil and duff-stored ribes seeds are not likely to germinate. If they do germinate, seedlings have little opportunity to become established in the thick mantle and in severe competition with established vegetation. Seedlings are not so vigorous when rooted in the organic layer as in mineral and burned-mineral soil, and thus are more susceptible to mortality from insolation, damping-off organisms, drought, winterkill, and insect attack.

In the stand 60 to 80 years old there were no ribes seedlings after mechanical removal of litter, but there was 60 percent germination when the litter and partly decomposed organic matter were removed, and 66 percent when all layers were removed.

Viable ribes seeds that fail to germinate at the time of a major disturbance eventually are killed by any drastic change in the once highly favorable seed-storage environment. The time required for dormant seeds to be devitalized after logging or fire depends upon how drastically environments are altered. In moderate to heavy partial cuttings the viable ribes seeds not germinating from the logging disturbance usually are devitalized in 5 to 15 years, and in light, partial cuttings in 15 to 25 years. Seeds not destroyed by fire on prescribed broadcast burns are killed in 4 to 6 years, depending upon the amount of organic mantle that is consumed by fire.

In 1940 new ribes and white pine seeds were sown in three surface soils under three intensities of light to determine the number of years required for the seeds to germinate and how long they retained their viability. Table 2 shows results of these germination tests for the first 5 years after sowing.

TABLE 2.—*Ribes and white pine germination (percent of total seed sowed) during a 5-year period after being sowed under different intensities of light and on various soil surfaces. Hannah flat, Kaniksu National Forest*

Year after sowing	Light intensity						Soil surface					
	Ribes [1]			White pine			Ribes [1]			White pine		
	Full sun	Half shade	Full shade	Full sun	Half shade	Full Shade	Litter	Burned mineral	Mineral	Litter	Burned mineral	Mineral
First	7. 5	8. 5	8. 2	20. 3	40. 3	60. 9	1. 2	11. 1	11. 8	15. 2	48. 2	58. 1
Second	9. 2	16. 6	19. 3	. 3	2. 6	5. 1	8. 3	21. 7	15. 0	5. 1	1. 5	1. 5
Third	. 1	1. 1	3. 9	0	. 4	1. 2	1. 1	1. 8	2. 5	. 7	. 3	. 5
Fourth	0	. 1	. 8	0	0	0	. 3	. 1	. 4	0	0	0
Fifth	0	0	. 4	0	0	0	. 2	. 1	. 2	0	0	0
Total	16. 8	26. 3	32. 6	20. 6	43. 3	67. 2	11. 1	34. 8	29. 9	21. 0	50. 0	60. 1

[1] Average for *Ribes lacustre* and *viscosissimum.*

New ribes seeds germinated in full sun for 3 seasons and in half shade for 4 seasons. In full shade seeds continued to germinate for 11 years (data not shown in table 2) when the surface soil was scarified lightly at 3-year intervals. Surface soils, litter, mineral, and burned mineral were similarly scarified for seed sown in full sun and in half shade, but no seed germinated beyond the third and fourth seasons, respectively.

245915—53——2

Most of the ribes seeds germinate within 3 years after logging or fire disturbs or consumes the organic soil mantle. Germination beyond the third year is usually related to the environment in prolonging seed viability.

Ribes seeds begin to germinate early in May and continue usually to about mid-July. Occasionally some will germinate after the first heavy rain in September, but fall germination is not common. The period of germination in the spring is shortest in full sun and longest in half shade. In full shade, because of surface soil drought, it is usually 10 to 20 days shorter than in half shade.

The number of ribes and white pine seeds germinating varies within each kind of soil surface (table 2). Litter provides the poorest medium, but the number of seeds germinating on a litter surface increases with the amount of canopy shade. Burned mineral soil provides the best surface under half and full shade. In full sun mineral soil is the best medium for *viscosissimum* and burned mineral soil the best for *lacustre* seed.

Seedling Survival

It has long been recognized that timber cover has an important effect on seedling survival and ultimate ribes suppression (fig. 2). The mortality of ribes seedlings is highest during the first growing season and the following winter. It decreases rather sharply after the second year, and bushes surviving more than three seasons usually are well established if they receive more than 50 percent of sunlight (table 3). On a site receiving less than 50 percent of sunlight and under good moisture conditions *lacustre* seedlings will persist longer than *viscosissimum* seedlings. The years of seedling survival depend upon the density of forest shade and the amount of root competition.

Table 3.—*Percent survival of ribes and white pine seedlings during the first 3 years after seeds were sowed under three intensities of light. Hannah area, Kaniksu National Forest*

Year after sowing	Ribes [1]			White pine		
	Full sun	Half shade	Full shade	Full sun	Half shade	Full shade
First	57. 1	67. 5	21. 4	63. 8	84. 2	76. 6
Second	46. 3	32. 6	. 6	58. 3	83. 7	70. 6
Third	43. 8	25. 7	. 4	57. 8	83. 3	64. 2

[1] Average for *Ribes lacustre* and *viscosissimum.*

The agencies causing seedling mortality, in the order of their importance, for ribes growing in full sunlight are insolation, winterkill, insects, damping-off organisms, and drought; in half shade they are winterkill, insolation, damping-off organisms, insects, and drought; and in full shade, winterkill, damping-off organisms,

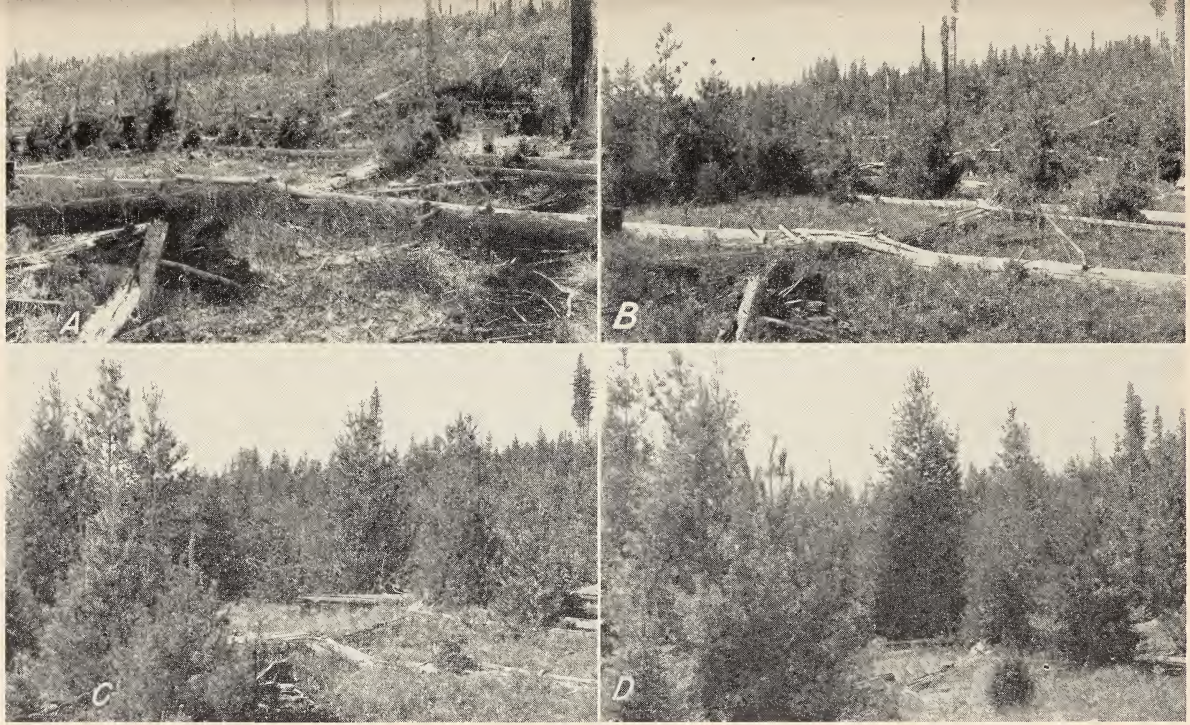

FIGURE 2.—Effect of a developing stand of western white pine on ribes suppression in the St. Joe National Forest. *A*, Natural regeneration of western white pine in 1934; area was clear-cut of timber in 1915, and logging slash was broadcast burned in 1917. These early logging practices produced an abundant and flourishing population of ribes. *B*, Same area in 1938, protected from blister rust; severe competition is beginning to develop between timber cover and brush cover. *C*, Same area in 1944; brush persists in small openings of forest stand. *D*, Same area in 1948; timber cover fully occupies site, ribes and brush are suppressed, and the establishment of new seedlings is prevented.

drought, and insects. Death of ribes seedlings during the winter months (November 1 to about April 15) results from a combination of damping-off organisms, suffocation, and exposure to freezing temperature.

BLISTER RUST INFECTION ON RIBES

All *Ribes* species in the western white pine region are susceptible to blister rust and capable of transmitting the infection to pine. The stream-type *petiolare* and *inerme* are the most susceptible to the rust and produce the most pine-infecting spores (Mielke and coworkers *9*). The amount of white pine infected with blister rust by these two species is greatest within 600 feet of the bushes. However, the major rust-control problems in white pine management are caused by the two upland species, *viscosissimum* and *lacustre*, because they are widespread and large numbers of them are on timber-producing slopes.

Weather and other environmental factors cause pronounced local and annual differences in the amount of infection of individual plants of the same *Ribes* species. Infection is heavier and telia are more abundant on plants growing in shade than in the open. Similarly, infection is heaviest in years of abundant summer rain, fog, or dew, and in localities where these conditions occur most frequently.

BLISTER RUST INFECTION ON PINE

Native tree species susceptible to blister rust in the western white pine region include the western white pine and the white-bark pine (*Pinus albicaulis*).

The susceptibility of white pine to blister rust is not affected by the size or age of the tree (Mielke *8*, Childs *2*). Large trees, because of more foliage, are better targets than small trees, but the rust kills small trees much faster. Damage is caused when the foliage between a completely encircling trunk canker and the roots of a tree is not enough to sustain growth, or when many twig and branch cankers seriously defoliate a tree. Trees are killed most rapidly through the dual action of trunk cankers and the increase in twig and branch infections that comes from continued exposure to the rust (Buchanan *1*).

The ability of western white pine stands to suppress ribes and to endure certain amounts of blister rust infection before irreplaceable crop trees are killed has an important bearing on their management. The amount of infection that will develop in a stand depends upon the number of ribes bushes, their position in relation to white pine, the number of years white pine is exposed to ribes, and weather conditions. How much damage a stand can tolerate depends upon its species composition, density, and age. A genetic difference may also give some trees greater resistance.

Large numbers of infected ribes bushes quickly cause heavy infection of pines nearby, but pines exposed over long periods to a few ribes bushes also become heavily infected. Pines closest to ribes plants are heavily infected quickly, but pines at greater distances also

become heavily infected when exposed over long periods. The relationship between the distance of pine from ribes and the percentage of trees infected is illustrated in table 4. C. R. Stillinger, of the Bureau of Entomology and Plant Quarantine, furnished data from around a single ribes bush having 53 feet of live stem.

TABLE 4.—*Pine infection in concentric zones around a single* Ribes viscossissimum *bush after exposure for 13 years*

Distance from ribes bush (feet)	Total trees (number)	Trees infected (percent)	Cankers per infected tree (number)
0 to 20	28	86	9. 2
21 to 40	149	63	5. 1
41 to 60	174	52	2. 8
61 to 80	299	45	2. 6
81 to 100	374	39	2. 1
101 to 120	469	32	2. 5
Total or average	1, 493	43	3. 1

Pines exposed to ribes bushes growing at a higher elevation than the stand become heavily infected, as do pines exposed over long periods to ribes growing at a lower elevation. Table 5 shows the percentage of white pine infected at various distances above and below a single *viscosissimum* bush in a 20-year-old stand. The stand was exposed to infection from 1933 to 1948. The ribes bush was eradicated on August 31, 1948, when it was nearly dead from natural suppression.

TABLE 5.—*Pine infection in semicircular zones at various distances above and below a single* Ribes viscosissimum *bush after exposure for 16 years*

Distance from ribes bush (feet)	Total trees (number)	Trees infected (percent)	Cankers per infected tree (number)
0 to 20:			
Above	42	81	22. 4
Below	15	87	38. 9
21 to 40:			
Above	99	65	4. 4
Below	139	86	15. 3
41 to 60:			
Above	118	47	1. 5
Below	231	59	4. 6
61 to 80:			
Above	124	40	. 8
Below	291	51	1. 5
Totals or averages:			
Above	383	53	4. 3
Below	676	62	6. 2

Both the quantity and duration of rain, fog, and dew late in summer and early in the fall affect pine infection. The rust sporidia, which are wind-disseminated from ribes leaves to white pine needles, will not germinate at a relative humidity below 97 percent. The optimum for pine infection is 100 percent or free water on the pine needles for 24 to 36 hours. Sporidia germinate at air temperatures from 34° to 70° F. (Hirt *5*). Favorable weather brought about heavy pine infection in 1927, 1933, 1937, and 1941.

A few instances are known where the rust has spread long distances from ribes to white pine. They have occurred in localities having frequent rain and fog, when large numbers of ribes a half to a mile to the windward of pine were producing sporidia. In the western white pine region ribes bushes growing in the open at an elevation higher than pine represent the extreme hazard for long-distance pine infection.

Species composition of a white pine stand and the stocking density of crop trees are important in evaluating how much blister rust damage can be tolerated before the yield is reduced below a level justifying the cost of protection. Stands that can tolerate the most damage are those containing a large proportion of evenly distributed crop trees. From yield studies the following estimates have been made of the number of evenly distributed dominant and codominant trees of all species per acre that would represent minimum stocking at different stand ages in the western white pine type.

Years	*Number of trees*	*Years*	*Number of trees*
20	400	80	200
40	300	100	175
60	250	120	150

In stands approaching these minimum stockings any loss becomes increasingly important as the proportion of less valuable species increases.

The time required for blister rust to damage a tree varies with its size or age. In a study of blister rust damage to merchantable western white pine in British Columbia and Idaho, Buchanan (*1*) concluded that the larger the tree the longer the period before damage. Table 6 gives his estimates of the years from pine infection until damage occurred.

BLISTER RUST IN RELATION TO TIMBER MANAGEMENT

The foregoing sections have outlined the major aspects of ribes occurrence and life history, and shown how blister rust affects white pine stands. A basic understanding of these factors should be helpful in controlling blister rust. Forest managers who understand the potentialities for economic loss by blister rust can estimate much better the need and opportunities for control in order to continue producing white pine.

It appears that only by correlating blister rust control and timber-management practices can white pine be grown on an economically sound basis. The following fundamentals must then be kept in mind.

1. Since blister rust is widely distributed throughout the western white pine region, the control problem is not one of eliminating the

TABLE 6.—*Effect of tree size on the time required for blister rust infections to damage pine trees* (*Buchanan 1*)

Height class (feet)	Trees	D. b. h. (average)	Time from infection until damage occurred
	Number	*Inches*	*Years*
5.0 to 10.0	7	0. 7	7 to 14
10.1 to 20.0	26	2. 3	8 to 15
20.1 to 30.0	29	3. 9	10 to 17
30.1 to 40.0	39	4. 5	10 to 17
40.1 to 50.0	57	5. 7	11 to 18
50.1 to 60.0	44	6. 9	12 to 19
60.1 to 70.0	35	7. 8	12 to 19
70.1 to 80.0	41	8. 5	12 to 19
80.1 to 90.0	45	10. 4	16 to 23
90.1 to 100.0	31	11. 3	17 to 24
100.1 to 110.0	26	15. 0	17 to 24
110.1 to 120.0	35	17. 8	18 to 25
120.1 to 130.0	60	20. 6	21 to 28
130.1 to 140.0	26	21. 8	20 to 27
140.1 to 150.0	24	23. 4	21 to 28
150.1 to 160.0	9	26. 7	23 to 30

rust but of continuing to grow white pine in spite of the disease. It is both impracticable and unnecessary to keep the disease wholly out of any particular stand, but it is important that rust damage be prevented from intensifying locally and from destroying solid blocks of pine within the stand.

2. Little evidence can be gathered to show that white pine is ecologically necessary for maintenance of an adequate forest cover in the Inland Empire region, but convincing evidence has been advanced to show that western white pine is needed to help supply the Nation's soft-pine lumber requirements (Matthews and Hutchison *7*). On the timber-producing lands the justification for blister rust control is economic. It is largely a long-time investment based on the belief that it is a sound public venture. The objective is to keep expenditures commensurate with expected benefits and, further, to obtain the greatest possible return in white pine harvest yields per dollar spent on blister rust control.

3. Timber-cutting methods can materially aid or impede control primarily through their influence on ribes establishment and development, although blister rust cannot be controlled by timber-management practices alone. Control and management practices must be harmonized in order to take full advantage of every natural aid that is practicable, as indicated by available information of ribes ecology and of the disease.

4. Timber management and disease-control objectives are in harmony. Both are best served by keeping the land fully occupied by growing timber. The more timber the less ribes, and the greater the yield of white pine per acre the less the cost of ribes control per thousand board feet.

5. Blister rust control is achieved primarily by suppression of ribes. Pruning infected pine stands is only a minor aid to control. The basic

strategy is to exhaust the stored-seed supply and eradicate existing ribes plants to prevent them from spreading the disease and producing more seed. Eradication today of every living ribes bush in the region would not end the control problem because of the stored seed.

6. Blister rust-resistant strains of western white pine or disease-resistant white pine hybrids are promising possibilities but not substitutes for blister rust control. At best they will provide resistant stock for planting after cutting or burning. They will not affect the necessity of protecting existing stands of white pine on which the industry will depend during the next 80 to 120 years. Because blister rust-resistant white pines would aid materially in the long run, research to discover or to develop such strains or hybrids should be pushed vigorously.

Cuttings in Mature and Overmature Stands

Cuttings in mature stands are of special significance in blister rust control, because they usually disturb the overstory and soil and start anew the regenerative cycles of both ribes and conifers (fig. 3). Age, vigor, and amount of defect of the stand, and ribes potential all have a bearing on the cutting method best suited to ribes suppression. The Forest Service has developed marking instructions for the white pine type designed to give the cutting practices that will best serve blister rust control and other silvicultural objectives.[5] Cuttings are of two classes—partial cuttings and clear-cuttings. Partial cutting as used here includes improvement and salvage cuttings, as well as shelter-wood and seed-tree cuttings.

Partial Cuttings

The major purposes in making partial cuttings are to control insects by cutting low-vigor trees and maintaining a vigorous and beetle-resistant growing stock, thus preventing future depredations; to place stands under management by cutting through them rapidly but lightly and opening them by roads to allow more intensive management; to harvest trees that are likely to die soon; to aid directly in blister rust control through ribes suppression; and to delay final decision and action on blister rust control and forest management measures until adequate information and facilities are available. The real importance of partial cuttings in this control is their effect on ribes germination and development and on the establishment of white pine reproduction rather than their influence on the probable future injury of blister rust to the mature trees of the residual stand. Cutting and harvesting methods affect ribes by changing forest-canopy density, by mechanically disturbing the forest floor incidental to logging, and through the use of fire in slash disposal.

LIGHT CUTTINGS

Light cuttings, which leave heavy residual stands and allow only 20 to 30 percent of full sunlight to reach the ground, will not induce

[5] Marking instructions for the white pine type in the northern Rocky Mountain region. U. S. Forest Service, Northern Rocky Mountain Forest and Range Experiment Station, May 1947. [Unpublished.]

FIGURE 3.—Blister rust control in relation to cuttings in mature stands. *A*, Light partial cutting, Bearpaw area, Kaniksu National Forest. Ribes will not survive under these conditions. *B*, Moderate partial cutting, Hannah Road area, Kaniksu National Forest. Cuttings of this kind with about 50-percent sunlight devitalize ribes seed and suppress most seedlings that germinate. *C*, Heavy partial cutting, Hollywood area, Clearwater Forest. These cuttings create ideal conditions for ribes-seed germination and seedling development, and thus are a severe blister rust hazard. *D*, Clear-cutting with prescribed broadcast burning of slash followed by planting to white pine, camp 15 area, Kaniksu National Forest. When properly executed, such cutting and burning can practically eliminate ribes.

or permit the development of an appreciable permanent ribes population (fig. 3, *A*). In well-stocked stands up to about 30 percent of the total board-foot volume can usually be removed and no more than 20 to 30 percent of full sunlight will reach the ground (Wellner *11*). Numerous ribes seeds probably will germinate after logging, especially along roads, in skid trails, and around burned slash piles, but seedling growth will be slow and mortality high (table 7). Light cuttings require little or no disposal of slash by fire; hence, ribes germination from this cause is not significant. Furthermore, forest canopies tend to close after light cutting and seedling survival becomes increasingly difficult.

TABLE 7.—*Germination and survival of ribes (number per acre) on typical cuttings during the first 3 years after being cut*

Type and location of cutting	Seeds germinating	Seedlings surviving	Type and location of cutting	Seeds germinating	Seedlings surviving
Light cutting:			Heavy cutting:		
Bearpaw Creek 1937	137	1	Big Creek	1,413	1,295
Bearpaw Creek 1939	119	2	Goose Creek	718	674
Rapid Lightning Creek	214	5	Potter Creek	1,146	993
Hannah Creek	33	2	East Fork Steamboat Creek	351	299
Deception Creek	107	3	Ames Creek	283	254
Average	122	3	Scaler Creek	3,316	3,187
Moderate cutting:			Mary Creek	2,011	1,954
Moore Creek	74	16	East Fork Potlatch Creek	823	801
Hannah Creek	41	7	Palouse River	1,903	1,879
East Fork Steamboat Creek	163	21	Hildebrand Creek	940	870
Swamp Creek	317	44	Mutton Gulch	1,763	1,668
East Fork Potlatch Creek	193	11	Sheep Mountain Creek	3,840	3,793
Hildebrand Creek	347	36	Average	1,542	1,472
Reeds Creek	231	19			
Average	195	22			

Blister rust damage after a light cutting is limited to the small amount of infection the ribes bushes can spread to the residual stand. The developed leaf surface will be small, and coniferous reproduction is of little silvicultural importance in lightly cut stands at this stage. Moreover, few ribes seeds will be produced to augment future ribes populations. Since one important objective in ribes eradication is the prevention of seeding, the lack of seeding in partial cuttings is worthy of emphasis.

Light cuttings made to harvest only a small part of the merchantable stand without encouraging natural tree reproduction will not create ribes suppression problems except in landings, along main roads, and on sites of continuously high soil moisture. On the contrary, selective cutting of a tree here and there should assist in reducing future work. Two or three partial cuttings, each causing some disturbance of the forest floor but not opening the canopy sufficiently to permit permanent ribes establishment, should exhaust much of the supply of stored

seed by inducing germination at times when seedlings cannot survive long. The slightly higher soil temperatures resulting from a partial opening of the forest canopy should shorten the period of ribes seed viability. Once the seed supply is largely exhausted, subsequent major harvest cuts, no matter how heavy, will not bring in appreciable numbers of ribes seedlings.

MODERATE CUTTINGS

Moderate cuttings, which permit 30 to 50 percent of full sunlight to reach the ground, can be great aids in ribes control (fig. 3, *B*). In well-stocked stands about 30 to 40 percent of the total board-foot volume usually can be removed and the light on the ground not be increased above 50 percent of full sunlight (Wellner *11*). Moderate partial cuttings alter the climatic conditions in the seed-storage environment yet provide adequate shade for suppression of ribes seedlings that develop after a logging disturbance. Hence the cuttings cause both the devitalization of ribes seed and the suppression of ribes seedlings.

Moderate numbers of ribes seeds germinate, but few survive during the first 3 years after a moderate partial cutting (table 7). Germination is largely completed during these 3 years, but plants will continue to die by suppression. Openings caused by logging where ribes bushes can become established will require direct control, but it will not be difficult or costly because only these easily reached openings need to be searched for ribes.

Moderate partial cuttings favor the establishment of coniferous reproduction, but because of the relatively heavy shade, tolerant species are favored over white pine. Therefore, within 20 to 30 years after establishment of reproduction, the overwood must be removed and the young stand weeded so that white pine will predominate in the next crop.

Moderate partial cuttings are not a panacea for growing white pine under the handicap of blister rust. In fact, the favoring of shade-tolerant species in the new stand is a serious disadvantage to continued production of pine. Furthermore, only vigorous stands can be partially cut with satisfactory results. Mature stands of poor vigor, and especially overmature stands, usually must be cut heavily or clear. But partial cuttings designed to shade out ribes can aid blister rust control more than any other cutting method, and should therefore be used wherever possible. They have the added advantage of deferring direct control action to the future, whereas with heavy cuttings or clear-cuttings the ribes-control job must be faced at once. Many heavily cut or clear-cut areas have been left out of blister rust control units, because the control job could not be done immediately. If these areas had been moderately cut, many of them could have been included in blister rust control units today, because partial cuttings would have largely taken care of the ribes problem or reduced necessary direct control to a point where it could have been handled with existing control facilities.

Cutting lightly or moderately to delay blister rust-control action is especially important at the present time, when heavily cut and clear-cut areas would be lost to another crop of white pine, at least

for the next rotation. On the other hand, the starting of a new stand can be delayed 20 to 30 years on light to moderate partial cuttings. By that time methods used to control blister rust should be improved and possibly cheaper. Moderate cuttings can maintain a greater acreage for potential white pine production.

Moderate partial cuttings can be a means of delaying final management decision. Today western white pine management is at the crossroads in certain respects. On some areas blister rust—and to a greater extent the new disease pole blight, the cause of which is not yet known—pose nearly impossible decisions for the white pine manager. Moderate partial cuttings allow a 20- to 30-year delay in management decision concerning the species to be grown after final harvesting of the present stands. Meanwhile the factual basis for reaching final decisions should be much better.

HEAVY CUTTINGS

Heavy cuttings thin the forest canopy sufficiently to allow good survival and development of both ribes and coniferous reproduction (Haig and coworkers *4*). In the past the worst possible blister rust hazards have often been produced by these cuttings (fig. 3, *C*). They permit light and temperature favorable to ribes development, and the considerable mechanical disturbance and the use of fire in slash disposal after logging stimulate germination of stored ribes seed. An abundant and flourishing ribes population develops (table 7) along with white pine reproduction, which is very susceptible to rapid destruction by the rust. Survival percentages for the heavy cuttings shown in table 7 are much greater than those for full sunlight given in table 3, because the site of the test in full sunlight was poorer and the ribes stands were much denser than any of those represented in table 7; hence competition was more severe and mortality greater.

Many heavy cuttings have been abandoned to rust because they caused ribes populations that precluded economic control. The Forest Service has discontinued the seed-tree method of cutting except in areas of low ribes potential, because the resulting blister rust hazard was too great to control.

However, the future of heavy cuttings looks much more promising since recent successes in killing ribes with the plant-growth hormone 2, 4, 5–T. Experiments suggest that the abundant ribes populations on heavy cuttings can be eradicated by broadcast spraying with low-cost herbicides, especially on areas that are accessible to truck- or trailer-mounted power sprayers or to helicopters (DeJarnette and coworkers [6]). If such broadcast spraying proves successful, heavy cutting methods, such as the seed-tree system which efficiently regenerates white pine (Haig and coworkers *4*), may again become desirable for certain conditions. Heavy cuttings that leave an adequate source of white pine seed favor the establishment and development of white pine.

In the event broadcast spraying proves capable of controlling ribes bushes on heavy cuttings at a reasonable cost, forest managers can

[6] Preliminary report of spraying ribes and brush with 2, 4, 5–T by helicopter in the western white pine region, by G. M. DeJarnette and C. J. Pederson, of the Forest Service, and V. D. Moss, of the Bureau of Entomology and Plant Quarantine. 1949. [Unpublished.]

assist by avoiding secondary forest disturbances. From a ribes-eradication viewpoint everything that is to be cut should be harvested at one time, or cedar poles and other subsidiary products should be removed in advance of the major logging operation. Managers can also assist by correlating ribes eradication with logging plans. The peak of ribes germination on cut-over areas comes the first or second year after logging. Consequently, ribes plants usually should be eradicated between 3 and 5 years after logging. Timing of control with logging is extremely important. Often it will be a race to get the ribes bushes out before blister rust infects white pine reproduction. Therefore, careful scheduling is necessary to spray the ribes plants at a time when most of them can be eradicated and still not wait so long that the pine become infected and new ribes seeds are produced.

Clear-Cuttings

Mature and overmature western white pine stands should be clear-cut (fig. 3, *D*) if they are of such low vigor that partial cutting is not satisfactory. All merchantable timber should be logged, and either the remaining trees, dead and alive, should be felled and broadcast burned or the slash should be broadcast burned first and then the remaining stand should be felled and the area reburned. After the ribes bushes have been eradicated, burned areas should be planted.

Clear-cutting followed by burning causes ribes seed to be released from thick insulating duff cover and encourages prompt and complete germination or devitalization of the seed that escapes destruction by fire. Germination is largely completed in 3 years. Hence, prescribed broadcast burning can be timed for maximum destruction of seed and plants. Eradication of surviving ribes bushes is comparatively easy, because they are readily visible and travel through the area is not difficult. Except on moist north and east slopes, many of the ribes seedlings die because of high temperatures and surface drought. On the more exposed sites few bushes will survive the initial season.

Clear-cutting followed by properly timed prescribed broadcast burning and planting will not only favor ribes suppression, but will also permit maximum white pine yields. Composition, density, and spacing of a stand can be controlled in plantations, so that almost ideal stocking of the desired species can be attained. Clear-cutting is excellent for white pine growth, which develops best in full sunlight.

Although ribes control is not difficult on most clear-cuttings that have been broadcast burned, in some instances, because of an unusual combination of abundant stored seed, light burning, and favorable moisture, a large and flourishing ribes population has become established. Blister rust soon infects these bushes, and any white pine on such areas has little chance of surviving the rust. Therefore, before clear-cut and burned tracts are planted, the exact ribes situation should be investigated. Planting must be delayed until practically all the ribes bushes have been eradicated.

On naturally regenerated clear-cut tracts, white pine seedlings appearing in the first few years probably will be killed by blister rust before the ribes bushes can be eradicated. Not much can be done about such situations, except to suppress the ribes as quickly as practicable and in the meantime accept seedling losses. If there is a natural

seed source, new pine seedlings may replace these infected ones. In any event, if the initial ribes bushes after a burning are eradicated before they produce seed, there will be little future ribes trouble whether the area is subsequently disturbed or not.

Clear-cutting followed by broadcast burning and planting appears to be the most efficient method of regenerating a new stand and protecting it from blister rust at low cost. However, the method does have the disadvantages of high initial investment and need for prompt and carefully timed action. The problems and expense of blister rust control must be faced at once on clear-cuttings, or the cutting area will be lost to white pine production for at least the next rotation. This is the fate of several National forest and State and private areas that were clear-cut without followup measures to eliminate ribes.

Clear-cutting should be followed by properly timed and correctly applied prescribed burning to be effective. Broadcast burning of heavy fuels always entails hazards and risks; therefore, managers are reluctant to burn. In addition, timing poses an administrative problem and burden which cannot always be met.

Clear-cutting followed by burning is sometimes criticized because of esthetics, damaging effects on soil, and detrimental influence on water runoff. As to the esthetics, burns are not pretty, but new vegetation will begin to reclothe burned areas in the white pine type within the first growing season after burning. However, possibilities of harm to the watersheds may be a more valid criticism, although burning as a silvicultural tool is restricted to such a small proportion of the total western white pine type that the temporary effect on the watershed is minor. Western white pine also are naturally fire forests; western white pine owes its present abundance and its very existence to fires that in the past periodically have reversed the trend toward a climax forest composed of western redcedar, western hemlock, and grand fir. Prescribed burning simulates a natural process that has gone on in nature for thousands of years—a process that has produced the valuable white pine stands of today.

If ribes eradication with 2,4,5–T and similar herbicides is realized, prescribed burning may be needed only for the destruction of unmerchantable timber and logging slash. Burning for fuel reduction alone is easier than burning with the additional purpose of destroying stored ribes seed and would greatly simplify the use of fire. With improved chemical methods clear-cutting systems, such as strip or block cuttings, may again become good practices for obtaining natural regeneration of white pine.

Cuttings Along Streams and on Ridge Tops

Timber management can further aid in blister rust control by conservative cutting of timber along streams and on ridge tops. Cutting lightly in creek bottoms to leave a rather full canopy will permanently suppress many ribes plants as well as protect streams from bank cutting and channel changing. Cuts along streams should not remove more than 25 percent of the merchantable volume at one time, and should be spaced at intervals of 20 to 30 years in order to maintain a canopy dense enough to shade out ribes. Western redcedar, Engel-

mann spruce, western hemlock, and grand fir are especially suitable for maintaining a dense canopy to suppress ribes.

Although ridge tops differ from stream bottoms in the tree species they support, as well as in topography, similar blister rust control measures are needed. In some drainages heavy potential ribes populations exist on ridges and upper slopes. If allowed to develop and persist, these bushes are a threat not only to white pine in the immediate vicinity but also to pine farther down slopes and in the basins below. Suppression can be aided materially by leaving a cap of uncut or very lightly cut timber on the upper slopes and along the ridge tops.

Prescribed Broadcast Burning

Prescribed broadcast burning is an important tool in the management of the western white pine type. It is the cheapest method of ridding cleared areas of large accumulations of slash, snags, and unmerchantable cull trees. It creates conditions favorable for forest regeneration, both natural and planted. Numerous tracts have been burned by prescribed broadcast methods and reasonably satisfactory methods have been developed (Davis and Klehm *3*, Lyman *6*, Forest Service[7]).

Prescribed burning for ribes suppression adds new and exacting demands to the requirements for burning to reduce fuel hazards. When properly timed and managed, broadcast burning can be of greater aid in the suppression of ribes than any other silvicultural measure. Until effective and economical methods of spraying with herbicides are developed, prescribed burning should play an important part in white pine management.

Although burning to aid in ribes eradication has been recommended for several years, very little acreage has been burned specifically for this purpose. In recent years partial cutting has replaced clear-cutting as the common harvesting method in managed stands of the white pine type; hence silviculturists have found few opportunities for testing burning as a ribes-control measure. The dangers inherent in broadcast burning have discouraged timber managers from using it. The dangers associated with holding slash for the necessary 3 to 5 years required for ribes germination have been another reason for reluctance to clear-cut and burn to destroy ribes. Getting just the right combination of weather conditions for hot but comparatively safe burning has been particularly difficult in the last few years. Finally, lack of facilities to conduct burning for ribes elimination has prevented action in some instances where the managers were willing to try. However, the principles involved are believed to be sound, and the adoption of prescribed burning is advocated.

Both single- and double-burning methods should aid in ribes eradication. When each should be used depends mainly on the fuel and topography of the particular tract. Either kind must burn hot to aid in ribes suppression. Well-planned layout of the area to be burned will contribute greatly toward success. Timing both with respect to ribes regeneration and to fuel conditions is especially important. Suf-

[7] Sale area betterment and stand improvement handbook for northern region. U. S. Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 1949. [Unpublished.]

ficient time must be allowed for seed stored in the duff to germinate or to be devitalized but not enough for the new ribes bushes to produce seed. The fire must spread over practically all the ground surface and consume the litter and small wood in order to destroy fuels and ribes seeds and plants.

Table 8 shows the large ribes populations on typical clear-cuttings 3 years after light-to-moderate prescribed broadcast burning of slash compared with the few ribes on similar cuttings that were burned hard. The slash was burned without waiting for germination and devitalization of ribes seed. The numbers of ribes seedlings shown are for samples selected to represent the intensity of burn specified. They do not indicate the kind of burn or the average ribes population for the entire location.

TABLE 8.—*Ribes seedlings (number per acre) on typical clear-cuttings 3 years after slash was burned*

Intensity and location of burn	Seedlings	Intensity and location of burn	Seedlings
Light to moderate:		Hard:	
Kalispell Creek, Area No. 1	1,043	Kalispell Creek, Area No. 3	11
Kalispell Creek, Area No. 2	461	Kalispell Creek, Area No. 4	3
Diamond Creek, Area No. 1	2,758	Diamond Creek, Area No. 2	1
Lamb Creek, Area No. 1	733	Pyramid Pass	7
Lamb Creek, Area No. 2	1,706	Brett Creek	10
Honey Creek	58	Potter Creek	16
Nicholas Creek	170	Ramskull Creek, Area No. 2	34
Ames Creek	622	Star Creek, Area No. 2	9
Ramskull Creek, Area No. 1	1,165	Star Creek, Area No. 3	0
Star Creek, Area No. 1	407	Beaver Creek	2
Alder Creek	263	Deer Creek	38
Average	853	Average	12

Single-Burn Method

Single burning for blister rust control is a modification of single burning for fuel reduction which has been widely applied in the white pine type. It probably has a wider field for use than double burning. The advantages are greater safety of control and greater adaptability in rough terrain. After all merchantable products have been removed from a tract, the residual stems should be felled or pushed over with a bulldozer. The prepared area should then be left for 3 to 5 years to await devitalization and germination of ribes seed. It must then be burned in the fall of the year. After another waiting period of 2 or 3 years while any remaining viable ribes seed germinate, the residual ribes plants should be eradicated. When examination shows that the tract is essentially free of ribes it should be planted.

Single burning is applicable to the following situations:

1. Areas where little standing defective timber is left after logging or where a single burn will leave insufficient fuels for a second burn.
2. Areas of steep and broken topography, where at best prescribed burning is hazardous even with all fuels on the ground.
3. Areas bearing much hemlock and with insufficient logging slash of white pine, grand fir, or cedar to carry the first fire needed in the double-burn method.

Single burning in conjunction with spraying of herbicides by helicopter may also prove useful to rehabilitate old burns that have regenerated to brushy growths. The brush killed with the spray is removed by a single burn, which clears the ground for planting.

Double-Burn Method

Double burning was developed as a cheaper and more efficient method than single burning where applicable for destroying ribes seeds and plants, logging slash, and unmerchantable trees. The first burn should be a slow or creeping fire which will destroy logging slash, kill as much as possible of the standing green defective timber by burning around the roots and the root collars, cause devitalization of ribes seed by altering storage conditions, and create conditions favorable for germination of seeds not destroyed. The second burn should be 3 to 5 years after the first. By this time the residual unmerchantable stand killed by the first fire will have disintegrated and built up sufficient fuels on the ground to carry the second burn. Some felling by power saw or bulldozer may be needed to augment the fuels on the ground. Most ribes seeds that have not died probably will have germinated. The second broadcast burn will lessen the fire hazard, destroy ribes bushes and many ribes seed not destroyed previously, and prepare the area for planting. As with single burns, no white pine should be planted until inspections of the tract show that ribes plants have been eliminated.

The double-burn method as outlined here was used to suppress ribes in a 55-acre cutting on the camp 15 area of Kaniksu National Forest (fig. 3, *D*). The overmature stand of western white pine, western larch, western redcedar, and defective western hemlock and grand fir was clear-cut of all merchantable trees in the winter of 1937–38. Logging slash was burned by the prescribed broadcast method in the fall of 1939. This burn killed practically all the standing green unmerchantable trees. A count 3 years later showed 40 ribes bushes established per acre. This low count was due to the low ribes potential of the area. In many cases thousands of ribes bushes per acre would have resulted from the first burn.

Three years after the first burn many of the standing trees had broken off; the remaining trees were felled, and the area was reburned in the fall of 1943. This second burn was hard and clean; the tract was in excellent condition for planting. Three years after the second burn only 0.5 ribes plant per acre was found. The area was planted with western white pine in 1944.

Double burning is more hazardous than single burning, because the fuels must be burned when they are very dry. It is also more difficult and hazardous to burn standing material than timber that has been

felled. Where all material has been felled, the concentrated fuels carry fire more readily.

Double burning is applicable to the following situations:

1. Flats, where fire is not so difficult to control as on slopes.
2. Tracts with sufficient fuels for two burns. Sufficient standing defective material must be left after logging to provide fuel for the second burn.
3. Tracts where logging slash is heavy and composed of white pine, grand fir, and western redcedar. Western hemlock slash will not readily carry a creeping fire. If logging slash is insufficient to carry the first burn, it may be augmented by felling some of the standing defective material.

Cuttings in Immature Stands

The objectives of stand improvement and ribes suppression in young stands are in close harmony. Cultural measures are intended to produce fully stocked, fast-growing stands of high quality at minimum expense, and hence with the least possible cutting and general forest disturbance. Ribes suppression is favored by retention of a full forest canopy and a minimum of ground disturbance. There are few reasons, consequently, why approved cuttings in young stands should contribute appreciably to the difficulties of ribes suppression. As will be brought out, practices undesirable for blister rust control are also undesirable silviculturally.

Cleanings

Cleanings are made in young stands between about 8 and 20 years old to improve species composition and eliminate excess stocking (fig. 4, *A*). They are the most economical and effective stand-improvement measures applicable to young stands in the western white pine type. Ribes bushes naturally flourish in such stands and must be suppressed to prevent injury to the pine whether the area is cleaned or not.

Cleanings do not appreciably aid or impede ribes suppression if the slash is not burned. However, burning of such slash may result in dangerous ribes populations.

Where slash has been piled and burned, ribes germination is high. In three areas in the Kaniksu National Forest only 1 ribes seed per acre germinated and 1 seedling survived on 1 area when the slash was not burned. However, in three similar areas in the Coeur d'Alene National Forest 92, 66, and 86 seeds per acre germinated and 87, 63, and 78 seedlings survived when the slash was piled and burned.

Fortunately, slash from cleanings does not need to be destroyed, and ground disturbance caused by cutting is slight.

Cleanings offer one of the most effective silvicultural tools for reducing blister rust control costs. By increasing the yield of white pine without increasing control costs, cleaning procedures broaden the white pine base to which the costs are charged.

Improvement Cuttings and Thinnings

Improvement cuttings and thinnings are made in stands between about 20 and 60 years old primarily to improve species composition.

FIGURE 4.—Blister rust control in relation to cuttings in immature stands. *A*, Young western white pines released by cleaning, Kaniksu National Forest. Cleaning does not aid or impede ribes suppression if cleaning slash is not burned. *B*, Young western white pine pruned of lower one-third of live crown, Kaniksu National Forest. Pruning does not affect ribes suppression if pruning slash is not burned. Pruning may eliminate dangerous blister rust cankers. *C*. Light crown thinning with slash lopped and scattered in pole stand, Coeur d'Alene National Forest. Such thinning does not affect the ribes problem adversely. *D*. Heavy low thinning with slash piled and burned in pole stand, Kaniksu National Forest. Such thinning results in appreciable numbers of ribes bushes.

reduce stand density, and improve stand quality, and secondarily to harvest limited quantities of merchantable products. In practice, improvement cuttings and thinnings in the western pine type are combined under the general term of "thinnings" and are more or less indistinguishable on the ground.

Three general classes of these cuttings can be recognized as follows:

1. Thinning from below, often termed "low thinnings," where everything but trees selected as final crop-tree possibilities is cut. The understory trees are all cleared away.
2. Crown thinning, or thinning from above, where possible crop trees are selected and cutting is limited to their release, principally in the tree crowns. The noncompeting overstory trees and most of the understory are left.
3. Selection thinning, where the largest dominant and codominant trees are cut.

Low thinnings, especially the heavier grades, are the least desirable from a ribes-suppression standpoint, because they open the forest cover considerably, especially near the ground, and mechanically disturb the forest floor (fig. 4, *D*). So much slash is produced that some burning is usually necessary, which further stimulates ribes development. As shown in table 9, light grades of low thinning do not present an appreciable ribes problem if slash is not eliminated, but heavy grades will, as slash disposal usually is necessary. Low thinnings have not been found to be silviculturally desirable in the Inland Empire, and they are not recommended because benefits generally are not commensurate with the costs.

TABLE 9.—*Germination and survival of ribes bushes (number per acre) during the first 3 years after various methods of thinning and slash disposal on areas of comparable ribes potential*

Method, location, and grade of thinning	Slash lopped and scattered		Slash piled and burned	
	Seeds germinating	Seedlings surviving	Seeds germinating	Seedlings surviving
Low thinning:				
Deception Creek:				
Light	6	2	128	57
Heavy	17	13	283	166
Crown thinning:				
Deception Creek:				
Light	1	1	29	18
Heavy	21	8	231	128
Selection thinning:				
Kalispell Creek	7	3	61	43

Crown thinnings and selection thinnings are more effective and economical silviculturally than low thinnings and do not seem to affect the ribes problem adversely (table 9, fig. 4, *C*). Cutting should be held to a minimum and confined largely to overstory trees. The forest canopy, especially near the ground, is not greatly opened by

crown or selective thinnings. Such thinnings do not disturb the ground surface appreciably. Furthermore, there is little slash and it does not need to be burned. Consequently, these thinnings do not favor ribes germination and development.

Pruning

White pine may be pruned of its lower branches primarily to increase the quality of the butt log. At times this pruning may also serve to eliminate blister rust cankers. Trees pruned to improve log quality should be 4 to 6 inches in diameter at breast height. Pruning for betterment of lumber should remove no more than one-third of the live crown; ordinarily it is not extended higher than 17 feet from the ground (fig. 4, *B*). In contrast, trees pruned to remove blister rust cankers are of smaller diameter and on them pruning is not carried to so great a height. Pruning to remove cankers may or may not improve lumber quality, depending on whether the trees are fully and properly pruned.

Pruning as a damage-prevention measure, is beneficial, but it should be practiced only to preserve adequate stocking of pine after blister rust control has been established. Infected branches, which might spread infection to the bole of the tree and thus cause its death, are removed. Pruning away live lower branches to reduce the infection target and thus lessen the likelihood of infection has sometimes been advocated. However, as long as a serious source of infection remains, reduction of target foliage cannot be regarded as an effective damage-prevention measure. In general, the cost of prevention pruning might better be invested in eliminating the alternate host—ribes. So long as pruning slash is not burned, pruning has little or no effect on ribes populations.

UNIT MANAGEMENT

Matthews and Hutchison (*7*) have stressed the importance of integrated management action. They said, "Make it a white pine project" rather than a blister rust control project. They clarified thinking on the working unit as the basic tract where all management action must be correlated and integrated. The working unit is defined as follows: [8]

> A working unit is a subdivision of the white pine zone which requires blister rust control and management as a unit. It is composed of one or a group of stands so situated topographically that the presence of ribes outside the boundaries of the working unit has a minimum effect on the white pine within the unit, and the benefits of ribes eradication within the unit are largely confined to it. It may be said that a working unit is that subdivision of the white pine zone that can be advantageously managed as a unit for the production of white pine at least cost under the handicap of blister rust. A working unit very often will consist of a single minor drainage.

The white pine region of the Inland Empire recently has been divided into these working units and each has been studied and analyzed in detail.[9] A number of these units have been selected which, on the

[8] Specifications of working unit analysis. U. S. Forest Service, Northern Region, Missoula, Mont., 1950. [Unpublished.]

[9] Bingham, R. T. Stocking-rust damage survey manual. U. S. Bureau of Entomology and Plant Quarantine, Northwestern Region, Office of Blister Rust Control, Spokane, Wash., 1949. [Unpublished.]

basis of over-all economic management, feasibility of control, cost of control per thousand board-feet of white pine produced, and timing of harvesting, fit into the present program for protection and management. The number of units in the program depends upon the size of the program and the costs of control. If the scope of operation is increased or costs are reduced, more units can be added. Some realignment of units is anticipated, because changes in management plans or other future events may lower the value of some units that have been classed as primary. Units have been assigned priority rankings for possible inclusion in the program.

The working unit is proving to be an excellent management device not only for planning but also for the actual field job of integration, correlation, and timing of all management practices. Today managers realize that their thinking must be in terms of unit management rather than individual-stand management. Plans for all stands or classes of stands within a unit must be correlated.

Within a primary unit the forest manager has the responsibility of picking and using practices that will produce the greatest amount of white pine at the least cost. To accomplish this he must constantly seek methods that will minimize ribes populations and increase white pine yields. At his disposal are numerous timber-management principles and techniques, most of which have been discussed in the foregoing sections. Important measures that he should consider include—

1. Reducing timber-production costs by applying efforts to the better sites where yields will be greater.
2. Minimizing the ribes-suppression job by use of long rotations.
3. Harvesting by methods that will suppress ribes and increase yields.
4. Burning by prescribed methods to reduce fire hazards and eradicate ribes.
5. Planting to rehabilitate areas and increase yields.
6. Cleaning to increase yields.
7. Thinning and improvement cutting to improve white pine quality and yields.
8. Pruning to improve quality and decrease infection.
9. Restricting cutting on stream bottoms and ridge tops where necessary to suppress ribes.
10. Timing all silvicultural operations to get maximum blister rust control.

The forest manager's responsibility does not end with the primary units. In at least the better secondary units he should adopt timber-management methods that will minimize ribes-suppression problems in order to maintain as much potential white pine-producing land as possible. Partial cuttings and prescribed broadcast burning are two timber-management practices that will be especially helpful in keeping blister rust in abeyance on the better secondary units.

SUMMARY

Experience in the western white pine type has shown the necessity for integrating silvicultural and other management operations with

blister rust control. Everyone engaged in management of western white pine should be cognizant of the opportunities for helping or hindering blister rust control by timber-management operations.

Timber management can help control white pine blister rust chiefly through measures that hinder the establishment and growth of ribes, the alternate hosts of blister rust.

Ribes populations of importance in blister rust control become established in full sun or lightly shaded sites after fires, logging, or other major disturbances to forest cover and forest soil. In forest stands of more than 50-percent shade, mortality of ribes seedlings is high and growth slow.

Basic strategy in ribes suppression is to exhaust the stored seed supply and to eradicate existing ribes plants to prevent them from spreading the disease and producing more seed. Effective exhaustion of the stored seed supply is accomplished by burning humus down to mineral soil, germinating seeds under forest shade, and devitalizing seed by removing sufficient forest cover to produce high soil temperatures.

The ability of white pine stands to tolerate rust damage varies with age, composition and density, and period of exposure to infection.

Light and moderate partial cuttings aid in ribes suppression. They can also be used to delay blister rust control action and management decision. They have the disadvantage of favoring shade-tolerant tree species in the reproduction stand.

Heavy partial cuttings, though usually successful in regenerating white pine, make conditions difficult for the economic control of blister rust. In this situation herbicides may provide a means for effectively combating blister rust.

Clear-cutting followed by properly timed prescribed broadcast burning and planting not only aids in ribes suppression but also provides for maximum white pine yields.

Conservative cutting on ridge tops and in creek bottoms aids in control by retarding growth of ribes bushes in the areas where eradication is difficult.

Cuttings, such as cleanings, thinnings, and pruning, in immature stands have little effect on ribes suppression. Cleanings help offset the costs of blister rust control by increasing white pine yields per acre and thus reducing control costs per thousand board-feet of white pine produced. Pruning aids in blister rust control by removal of infected branches. Thinnings and improvement cuttings increase quality and yields of white pine.

The white pine working unit has become the basic field unit where complete correlation, integration, and proper timing of blister rust control with all forest management practices must be accomplished.

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